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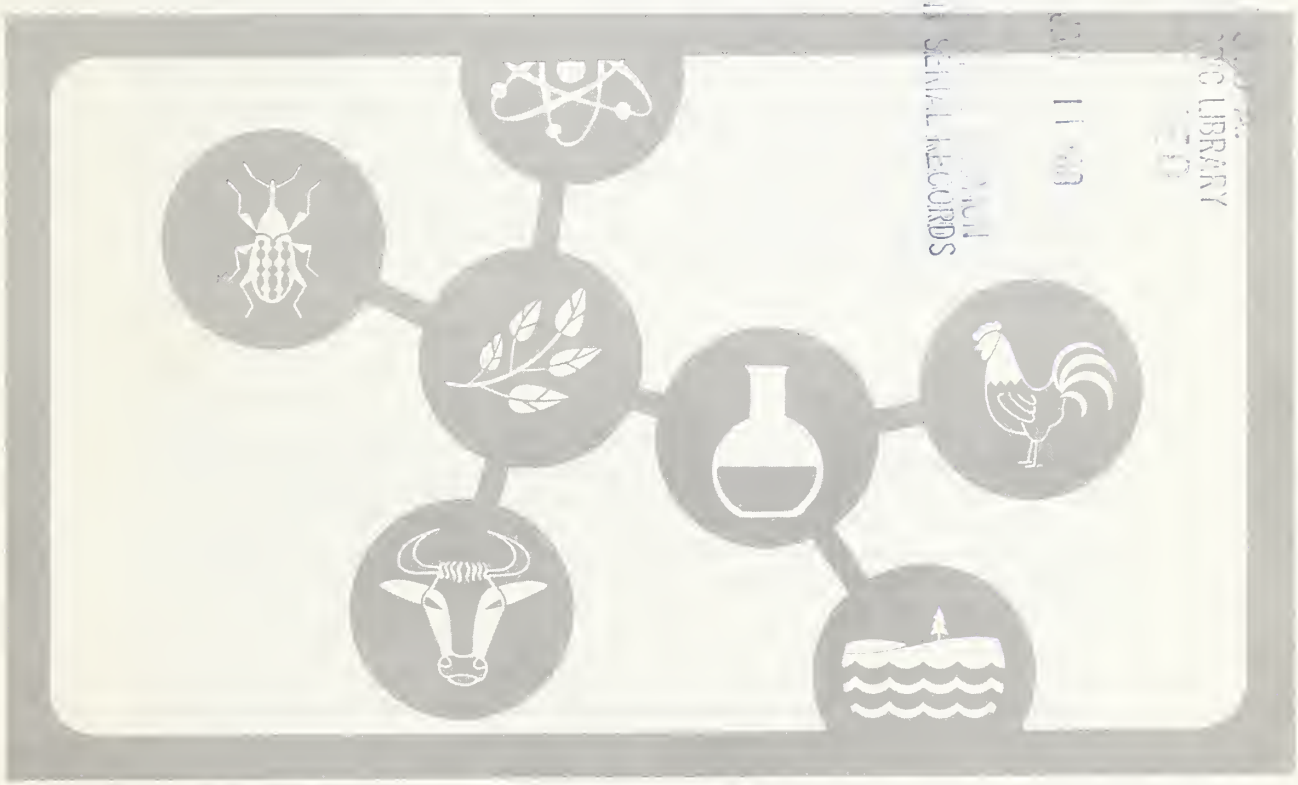

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Effects of Planting Location and Temperature on the Oil Content and Fatty Acid Composition of Sunflower Seeds

By J. A. Robertson, W. H. Morrison III, and R. L. Wilson[1]

ABSTRACT

Total oil content and fatty acid composition were determined on the seed of sunflowers, *Helianthus annuus* L., from the 1976 and 1977 U.S. National Sunflower Performance Trials. In 1976, oil content of seed of 10 sunflower hybrids and 2 varieties from 24 locations in the United States and 1 location each in Canada and Mexico ranged from 33.2% to 54.2% and averaged 46.8% for all locations. Oleic acid content ranged from 15.1% to 59.3% and averaged 34.3% for all locations, whereas linoleic acid content ranged from 31.8% to 74.0% and averaged 55.7%. Palmitic and stearic acids averaged 5.3% and 3.8%, respectively. In 1977, oil content of seed of 12 sunflower hybrids and 2 varieties from 36 locations in the United States and 1 location each in Canada and Mexico ranged from 33.2% to 53.9% and averaged 46.3%. Oleic acid content ranged from 13.7% to 59.2% and averaged 31.1% for all locations, whereas linoleic acid content ranged from 32.4% to 75.9% and averaged 59.5%. Palmitic and stearic acids averaged 5.4% and 3.9%, respectively. Analysis of variance showed a highly significant difference in oil content between hybrids and varieties in 1976 and 1977. For both years, temperature and latitude had a highly significant effect on fatty acid composition. Oleic acid was positively correlated with minimum temperature (r=0.87), whereas palmitic (r= - 0.71), stearic (r= - 0.57), and linoleic (r= - 0.83) acids were negatively correlated with minimum temperature. A linear regression model of linoleic acid content versus average minimum temperature during seed development showed a straight-line fit of the data, with R^2=0.69. The results of the study suggest that sunflower oil for products requiring highly polyunsaturated oil, such as margarine and salad dressings, might be obtained from planting locations above 39° latitude and that sunflower oil used in snack-food frying might be obtained from planting locations below 39°. Index terms: fatty acids, latitude, linoleic acid, oilseeds, oleic acid, palmitic acid, stearic acid, sunflowers, sunflower seed oil, temperature.

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INTRODUCTION

In 1978, a record 2.7 million acres of sunflowers were produced in the United States (Minnesota Crop and Livestock Reporting Service 1978), and a long-term expansion potential of 7 million acres was forecast (U.S. Foreign Agricultural Service 1977). Only about 10% of the oilseed-type sunflowers are used in domestic markets; the remainder are being exported (U.S. Economics, Statistics, and Cooperative Service 1978). Since sunflower oil is such a nutritious vegetable oil, the potential for expanding domestic markets in the United States is great. Test marketing of sunflower-oil products is being conducted by Lever Brothers (Promise margarine), Hunt-Wesson (Sunlite salad oil), and Proctor & Gamble (Puritan vegetable oil). These and other new products will mean a greater demand for sunflower oil.

The fatty acid composition of sunflower oil is known to vary, depending upon the temperature during seed development (Canvin 1965, Robertson et al. 1971, 1978). Linoleic acid content of oil from commercial varieties has been found to range from 31.4% for plantings in Texas (Robertson et al. 1971) to 75.5% for plantings in Canada (Robertson et al. 1978). Putt et al. (1969) reported inbred lines with linoleic acid content as high as 81.8%. Therefore, differences in fatty acid composition make usage of sunflower oil in a wide range of food applications possible and desirable.

We report here the effects of planting location (latitude) and temperature on the total oil content and fatty acid composition of the seeds of commercial hybrids and open-pollinated varieties of sunflower, *Helianthus annuus* L., grown at various locations in 1976 and 1977.

MATERIALS AND METHODS

Sunflower seed samples were obtained from the 1976 and 1977 U.S. National Sunflower Performance Trials. These trials were a cooperative effort of commercial seed companies, the National Cottonseed Products Association (NCPA), and the Sunflower Association of America. Dalton E. Gandy (deceased), formerly of NCPA, was project coordinator.

In 1976, seed of 10 sunflower hybrids and the 'Sputnik 71' and 'Peredovik 66' varieties were obtained from 24 locations in the United States and 1 location each in Canada and Mexico. In 1977, seed of 12 hybrids and the 'Sputnik 71' and 'Peredovik 66' varieties were obtained from 36 locations in the United States and 1 location each in Canada and Mexico. The experimental design of the plantings was usually a randomized complete-block design with four replications. Row width varied from 30 to 40 in and row length from about 20 to 40 ft. Seed were usually hand-harvested for up to 4 weeks after they had reached physiological maturity (the point at which oil filling and seed weight are maximum), depending on weather and availability of equipment.

Foreign material was removed from seed before analysis by hand-picking and sieving. Total oil content was determined in duplicate on three composite samples of 12 to 14 g each of dry seed (130° C for 1 h) by a Newport MK III wide-line nuclear magnetic resonance analyzer. Fatty acid composition was determined in duplicate on two composite samples by gas-liquid chromatography (Robertson et al. 1978). Moisture content was determined by AOCS method Ai 2-75 (American Oil Chemists' Society 1975). Mean daily maximum and minimum temperatures at each planting location were obtained for the period of full bloom until seed harvest. Duncan's multiple-range test was used to identify significant differences between the oil contents of the individual hybrids or varieties.

RESULTS AND DISCUSSION

The effects of planting location and temperature on the average oil content and fatty acid composition of 10 hybrids and 2 varieties of sunflower grown at 26 locations in 1976 are shown in table 1. Average oil contents ranged from a low of 39.2% at Dawson, Ga., to a high of 51.8% at Redfield, S. Dak., with an overall average of 46.8%. Average oleic acid contents ranged from a low of 17.2% at Medford Oreg., to a high of 54.2% at Gainesville, Fla., with an overall average of 34.3%. Average linoleic acid contents ranged from a low of 37.2% at Gainesville, Fla., to a high of 71.2% at Morden, Manitoba, with an average of 55.7%.

Table 2 shows the effects of planting location and temperature on the oil content and fatty acid composition of 12 hybrids and 2 varieties of sunflower grown at 38 locations in 1977. Average oil contents ranged from a low of 37.6% at Río Bravo, Mexico, to a high of 51.8% at Brooksville, Miss., with an overall average of 46.3% . Average

Table 1.—Effects of planting location and temperature on the oil content and fatty acid composition of sunflower seeds, 1976

[In order of increasing latitude]

Location	Planting date	Degrees latitude	Temperature (°C)[1]			Oil content (%)[2]		Fatty acid composition (%)							
			Mean daily max.	Mean daily min.	Daily avg.	Avg.	Range	Palmitic		Stearic		Oleic		Linoleic	
								Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Río Bravo, Mexico	3-22	26	33.2	22.6	27.9	48.1	43.8-50.7	5.0	4.1-5.3	3.0	2.5-3.4	47.8	40.0-55.8	43.4	37.8-50.2
Corpus Christi, Tex.	4-9	27.5	31.8	23.4	27.7	48.8	44.1-52.1	4.7	4.4-5.0	2.7	1.9-3.8	45.2	37.8-53.8	46.0	36.7-53.4
Gainesville, Fla.	4-14	29.5	32.6	21.3	26.9	47.7	44.0-51.3	4.6	4.4-5.1	3.0	2.5-3.3	54.2	49.6-59.3	37.2	31.8-41.9
Tifton, Ga.	4-14	31.5	32.0	20.3	26.2	49.7	45.9-52.8	4.6	4.2-5.0	2.6	2.0-4.2	48.0	41.6-54.5	44.2	36.7-51.2
Dawson, Ga.	3-18	32	33.3	21.0	27.2	39.2	33.2-44.7	5.3	4.9-5.8	3.7	3.2-4.2	37.0	32.8-43.7	52.6	46.2-56.7
Auburn, Ala.	4-20	32.5	31.4	20.3	25.8	48.4	46.9-49.8	5.2	4.7-5.7	3.0	2.2-3.3	37.8	33.3-42.9	53.0	47.7-57.2
Brooksville, Miss.	4-29	33	33.4	18.8	26.2	50.5	47.8-53.2	5.5	5.3-5.9	2.7	2.3-3.0	37.8	33.7-44.3	53.0	46.5-57.1
Lubbock, Tex.	4-23	34	29.1	17.2	23.1	46.5	42.4-47.7	4.6	4.3-5.0	4.3	3.5-5.3	43.4	39.9-47.4	46.2	42.0-50.5
Plainview, Tex.	4-27	34	28.1	14.9	21.5	46.2	41.5-48.9	5.5	5.1-5.8	4.5	3.9-5.2	34.7	30.8-39.1	53.8	48.9-57.3
Clovis, N. Mex.	4-1	34	31.3	15.7	23.6	45.1	43.9-46.4	4.9	4.6-5.2	4.9	4.6-5.3	39.3	35.6-41.8	49.5	46.9-52.6
Laurinburg, N.C.	6-1	35	27.8	13.1	20.4	48.9	47.1-51.3	5.3	4.9-5.5	2.6	1.9-3.4	28.2	25.0-32.0	62.7	58.5-65.4
Bushland, Tex.	5-7	35	30.4	16.1	23.3	42.3	38.4-44.9	5.4	5.1-5.9	4.9	4.2-5.8	38.7	37.0-41.1	49.6	46.2-51.3
Clarkedale, Ark.	4-5	35.5	31.4	18.6	24.2	47.2	45.5-50.1	4.6	4.3-5.1	3.3	3.0-3.7	49.3	46.2-52.1	41.7	38.7-44.5
Jonesboro, Ark.	4-20	35.5	31.7	18.6	25.1	44.0	40.6-46.6	5.1	4.8-5.5	3.2	2.8-3.9	46.0	42.6-49.1	45.1	42.3-48.6
Leoti, Kans.	5-7	38	31.5	15.1	23.5	48.0	46.2-52.2	5.1	4.7-5.5	4.5	3.8-5.1	38.7	35.0-42.6	50.9	47.1-54.8
Davis, Calif.	5-26	38.5	30.7	12.7	21.7	48.8	46.0-51.2	5.8	5.4-6.4	4.0	3.3-4.7	19.0	17.5-19.6	70.7	69.6-72.5
Woodland, Calif.	4-19	38.5	34.3	14.3	24.3	45.3	42.8-48.2	5.2	4.2-5.7	4.2	3.1-5.5	26.8	21.4-29.4	63.3	58.7-68.5
Ft. Hays, Kans.	5-19	38.5	31.9	16.4	24.2	40.6	38.6-43.8	5.9	5.6-6.3	4.4	3.5-5.1	36.6	33.0-41.7	51.8	46.9-55.9
Beltsville, Md.	5-24	39	29.1	15.3	22.2	44.8	42.3-47.7	5.2	4.6-5.8	3.9	3.3-4.6	31.1	25.5-35.7	59.0	54.8-64.3
W. Lafayette, Ind.	5-18	40.5	27.3	15.2	21.8	50.5	48.8-52.6	5.2	5.0-5.4	3.8	2.9-4.5	24.0	22.1-25.8	66.4	63.2-69.6
Medford, Oreg.	4-5	42	28.5	11.1	19.8	51.4	49.1-54.2	6.0	5.4-6.5	4.7	4.3-5.3	17.2	15.8-18.6	71.1	69.2-73.1
Sheridan, Wyo.	5-18	44.5	27.3	8.4	17.9	45.6	44.5-46.8	5.9	5.6-6.2	4.3	3.4-5.2	19.3	18.3-20.3	69.5	67.4-71.7
Redfield, S. Dak.	5-25	44.5	29.3	10.4	19.9	51.8	49.3-53.8	5.6	5.2-6.0	4.3	3.9-5.0	22.5	20.0-27.8	66.9	61.7-69.4
Casselton, N. Dak.	5-7	46.5	30.4	14.4	22.4	45.0	41.3-47.8	5.7	5.4-6.2	3.7	2.6-4.8	29.0	24.9-34.9	60.9	54.1-65.9
Crookston, Minn.	5-17	47	29.2	13.2	21.2	43.9	40.9-46.5	5.5	5.0-5.8	4.2	3.7-5.1	21.3	18.2-24.8	68.1	65.1-71.5
Morden, Manitoba	5-18	49	23.8	10.2	16.9	49.8	48.1-51.5	5.5	5.0-6.4	3.5	2.6-4.2	18.9	16.2-21.6	71.2	68.3-74.0
Overall average	....	....	....	....	....	....	46.8	.....	5.3	.....	3.8	.....	34.3	.....	55.7	.....

[1]Average daily temperature from flowering to maturity.

[2]Dry-weight basis.

Table 2.—Effects of planting location and temperature on the oil content and fatty acid composition of sunflower seeds, 1977

[In order of increasing latitude]

Location	Planting date	Degrees latitude	Temperature (°C)[1]			Oil content (%)[2]		Fatty acid composition (%)							
			Mean daily max.	Mean daily min.	Daily avg.	Avg.	Range	Palmitic		Stearic		Oleic		Linoleic	
								Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Río Bravo, Mexico	3-25	26	33.4	23.1	28.3	37.6	33.2-41.9	5.0	4.7-5.2	3.1	2.7-3.8	45.9	40.8-58.4	45.5	32.6-50.8
Weslaco, Tex.	8-8	26	31.1	18.8	25.0	48.5	46.7-52.6	4.8	4.1-5.2	3.6	3.0-4.2	31.9	28.1-38.6	59.5	52.8-63.6
Corpus Christi, Tex.	3-28	27.5	33.2	23.8	28.8	48.5	43.2-52.5	4.8	4.5-5.1	2.0	1.6-3.0	50.2	39.8-59.2	42.2	32.4-53.3
Gainesville, Fla.	2-18	29.5	33.2	17.7	25.4	48.7	46.0-51.1	5.3	4.7-6.1	3.3	2.6-4.2	40.1	30.5-47.1	50.4	43.2-58.3
Tifton, Ga.	4-13	31.5	35.5	21.8	28.7	48.2	42.8-52.4	5.3	4.8-5.8	3.1	2.5-4.0	46.0	42.1-49.6	45.3	41.1-49.3
Auburn, Ala.	4-14	32.5	33.7	21.2	27.4	46.0	43.0-50.0	5.9	4.7-6.5	2.8	2.2-3.6	35.0	31.7-38.4	55.9	51.7-59.5
Brooksville, Miss.	4-15	33	34.5	19.6	27.1	51.8	49.8-53.9	5.1	4.6-5.4	2.1	1.4-2.8	46.2	41.7-49.7	45.4	41.9-49.9
Experiment, Ga.	4-26	33	32.3	20.1	26.2	48.5	44.8-52.5	5.5	5.0-5.9	2.8	2.1-3.5	38.8	35.0-44.2	52.2	47.2-56.7
Plainview, Tex.	4-26	34	33.2	20.2	27.7	38.6	36.9-42.7	5.7	5.1-6.1	3.6	2.8-4.8	36.4	33.4-40.3	54.0	49.9-57.2
Clovis, N. Mex.	4-4	34	31.9	19.3	25.6	44.5	38.6-43.5	5.5	5.3-5.6	4.5	3.9-5.1	37.0	33.9-39.4	52.7	50.8-56.2
Laurinburg, N.C.	6-15	35	31.4	18.8	25.1	49.3	47.0-51.2	5.4	5.0-6.0	2.8	2.3-3.8	32.0	28.4-37.4	59.1	50.0-66.2
Pinetree, Ark.	5-13	35	32.7	20.3	26.5	47.6	44.8-50.9	5.2	4.9-5.6	2.5	1.9-3.1	43.7	39.4-47.6	47.9	42.9-52.6
Bushland, Tex.	5-6	35	31.3	19.6	25.4	45.0	40.9-48.9	5.4	5.0-5.7	3.5	3.1-4.2	39.2	34.6-42.8	50.6	49.0-56.5
Keiser, Ark.	4-12	35.5	32.6	24.7	28.7	49.8	47.3-53.0	5.1	5.0-5.5	2.8	2.5-3.4	50.2	48.5-52.7	41.3	38.1-43.6
Batesville, Ark.	5-12	35.5	34.7	21.2	27.9	50.8	48.2-53.0	5.3	4.8-5.6	2.8	2.4-3.3	39.4	32.1-44.3	51.9	46.5-59.7
Farmington, N. Mex.	5-9	36.5	33.8	15.9	24.9	39.2	35.1-45.0	5.0	4.4-5.3	4.4	3.7-5.3	36.8	33.0-41.3	53.3	50.1-57.5
Sikeston, Mo.	5-20	37	31.7	20.4	26.1	42.4	39.5-49.1	5.3	4.8-5.8	3.4	3.0-3.6	38.5	27.7-48.2	52.3	42.6-62.8
Cortez, Colo.	6-1	37	28.8	14.5	21.7	47.9	43.9-52.1	6.3	6.1-6.7	5.3	4.9-6.0	17.1	16.0-19.2	70.7	68.8-72.1
Garden City, Kans.	5-31	38	29.6	15.3	22.4	41.1	38.7-44.9	4.9	4.6-5.6	4.2	3.5-5.1	38.8	28.5-45.0	51.6	45.2-62.0
Leoti, Kans.	5-3	38	32.1	17.3	24.7	45.4	41.2-50.5	4.8	4.3-5.1	4.1	3.1-5.1	38.2	32.9-47.3	53.2	46.2-58.2
Davis, Calif.	5-19	38.5	32.1	15.1	23.6	47.3	44.9-50.5	6.3	5.9-6.7	3.8	3.2-4.8	17.3	15.9-19.2	72.0	69.4-75.0
Ft. Hays, Kans.	5-18	38.5	29.8	17.7	23.8	48.6	44.1-52.4	4.9	4.2-5.3	4.0	3.4-4.8	40.7	35.8-48.0	49.8	42.1-53.4
Grand Junction, Colo.	5-15	39	30.2	9.6	19.9	44.5	38.8-48.9	5.3	4.4-5.7	4.8	4.2-5.7	26.2	24.5-29.2	63.3	60.0-66.2
Beltsville, Md.	5-17	39	31.1	19.1	25.1	46.6	43.6-49.2	5.0	4.6-5.5	3.6	2.9-4.4	40.2	32.8-43.2	50.6	46.7-57.7
Torrington, Wyo.	5-11	42	27.7	9.5	18.6	44.9	41.6-49.5	5.0	4.6-5.5	5.5	4.8-6.4	23.8	21.3-27.1	65.1	61.5-67.7
Medford, Oreg.	4-8	42	32.4	12.8	22.6	45.8	43.3-48.9	6.7	6.3-7.0	4.1	3.3-4.9	19.5	17.5-21.5	68.9	66.3-71.4
Arlington, Wis.	4-24	43	22.0	11.2	16.6	48.3	46.4-49.5	5.2	4.9-5.8	4.3	3.5-5.4	22.5	20.1-25.9	67.5	64.1-70.6
Sheridan, Wyo.	5-3	44.5	25.8	7.3	16.6	45.8	43.6-48.3	5.7	5.0-6.2	5.2	4.5-6.0	18.4	17.1-20.2	70.2	67.5-72.3

Redfield, S. Dak.	5-17	44.5	23.8	10.3	17.1	47.7	46.3-49.7	4.9	4.1-5.3	4.7	4.1-5.4	21.2	19.7-22.9	68.8	66.5-70.8
Morris, Minn.	5-19	45	22.4	10.3	16.4	51.1	49.6-53.4	5.2	4.8-5.7	4.6	3.6-6.1	18.9	15.8-21.1	70.6	66.5-73.5
Spooner, Wis.	5-17	45.5	20.3	6.9	13.7	48.2	47.2-49.6	5.0	4.6-5.2	5.3	4.5-6.2	18.9	16.5-21.7	70.2	63.8-74.6
Norcross, Minn.	5-26	45.5	23.7	11.3	17.5	44.9	41.0-49.2	4.4	4.1-4.7	3.8	2.9-5.0	24.2	21.7-27.5	67.4	62.5-70.5
Breckenridge, Minn.	5-7	46	25.6	13.1	19.3	49.8	47.3-53.8	5.1	4.7-5.5	3.9	3.1-4.7	20.6	19.1-22.2	69.9	67.4-71.6
Moscow, Idaho	4-28	46	31.4	11.2	21.3	42.1	39.5-46.9	6.6	5.9-7.2	4.3	2.9-5.7	18.4	15.6-22.4	70.2	64.9-74.5
Casselton, N. Dak.	5-9	46.5	23.7	12.1	17.9	46.8	45.1-50.3	4.9	4.5-5.3	4.6	4.0-5.8	17.3	16.3-18.4	72.7	71.0-73.9
Rathdrum, Idaho	4-21	47	30.2	11.5	20.8	43.5	41.5-47.4	6.0	5.3-6.6	5.7	4.6-6.9	14.8	13.7-15.5	72.9	71.3-74.2
Crookston, Minn.	5-9	47	22.2	10.6	16.4	47.9	45.0-51.7	5.0	4.6-5.4	5.1	4.3-6.1	15.9	15.4-16.8	73.3	72.2-74.0
Morden, Manitoba	5-11	49	20.4	8.9	14.7	47.8	42.9-50.9	5.0	4.5-5.4	4.3	3.7-5.5	15.6	14.7-16.6	74.7	73.5-75.9
Overall average	...	...	...	...	...	46.3	...	5.3	...	3.9	...	30.9	...	59.3	...

[1] Average daily temperature from flowering to maturity.
[2] Dry-weight basis.

oleic acid contents ranged from 14.8% at Rathdrum, Idaho, to 50.2% at Corpus Christi, Tex., and Keiser, Ark., with an average of 30.9%. The average linoleic acid contents ranged from a low of 41.3% at Keiser, Ark., to a high of 74.7% at Morden, Manitoba, with an average of 59.3%.

The oil content and fatty acid composition of the individual sunflower hybrids and varieties planted in 1976 are shown in table 3. Total oil contents of the hybrids and varieties at the 26 locations ranged from 33.2% to 54.2% and averaged 46.8%. Oleic acid contents ranged from 15.1% to 59.3% and averaged 34.3%, whereas linoleic acid contents ranged from 31.8% to 74.0% and averaged 55.7%. Palmitic and stearic acid contents averaged 5.3% and 3.8%, respectively.

Table 4 gives the oil content and fatty acid composition of the sunflower hybrids and varieties planted in 1977. Oil contents at the 38 locations ranged from 33.2% to 53.9%, averaging 46.3%. Oleic acid contents ranged from 13.7% to 59.2% and averaged 31.1%, slightly lower than the average for the 1976 plantings. Linoleic acid contents ranged from 32.4% to 75.9% and averaged 59.5%, slightly higher than the average for the 1976 plantings. Palmitic and stearic acid contents averaged 5.4% and 3.9%, respectively.

Analysis of variance showed a highly significant difference in oil contents between hybrids in 1976 and 1977 ($P<0.0001$). The same varieties tended to give consistently high or low total oil contents in both years. 'Sputnik 71', an open-pollinated variety, had the highest oil content in both years (tables 3 and 4) but did not produce the highest oil yield because of low seed yield, particularly in 1977 (tables 5 and 6). The oil-yield data show that the hybrids or varieties with the highest oil content will not necessarily give the highest oil yield. As would be expected, location affected oil content of hybrids significantly ($P<0.0001$), because of different environmental and agronomic conditions.

Temperature and latitude had no significant effects on total oil contents (table 7). Nevertheless, sunflowers grown at the cooler locations and at latitudes above 39° had slightly higher oil contents than those grown at the warmer locations, below 39° latitude. As expected, latitude was significantly correlated with average daily temperature (r=-0.84) for the planting locations. Canvin (1965) reported higher oil contents for rape and flax seed at the lowest temperatures and continual decreases in oil contents with increases

Table 3.—Oil content and fatty acid composition of the seeds of sunflower hybrids and varieties grown at 26 locations in 1976

[In order of increasing oil content]

Hybrid or variety	Oil content (%)[1]		Fatty acid composition (%)							
			Palmitic		Stearic		Oleic		Linoleic	
	Avg.[2]	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Sun Hi 304	45.2a	33.2-51.8	5.5	4.7-6.3	3.4	2.0-4.9	33.3	15.1-50.6	56.9	40.2-73.1
'Peredovik 66'	45.8a	36.1-51.9	5.0	4.1-5.9	3.9	2.7-5.3	35.9	18.4-59.0	54.1	32.5-72.8
Sunbred 223	45.9a	40.4-51.4	5.3	4.6-6.2	3.9	2.7-5.2	36.1	16.5-54.6	53.6	36.7-72.3
Cargill 204	45.9a	36.7-52.6	5.5	4.4-6.3	3.5	1.9-5.1	33.4	15.8-51.9	56.7	39.1-73.0
Hybrid 8944	46.1ab	39.3-50.4	5.4	4.3-6.1	3.5	2.2-5.3	35.2	17.3-54.7	54.9	36.4-70.6
Sunbred 212	46.9bc	38.2-53.2	5.1	4.4-6.1	3.7	2.5-4.8	35.7	18.3-59.3	54.5	31.8-71.7
DO 410	47.1c	41.6-52.7	5.1	4.3-6.4	4.2	2.7-5.8	34.3	17.4-55.7	55.3	35.4-71.9
Sun Hi 301	47.3cd	39.8-53.0	5.2	4.5-6.2	3.7	2.6-4.9	32.8	17.1-56.7	57.3	34.9-73.2
Sun Gro 372	47.4cde	36.1-52.8	5.4	4.4-6.1	4.0	2.4-5.1	34.0	17.5-50.4	55.2	41.9-71.7
Sun Gro 380	48.1de	42.4-53.8	5.3	4.5-6.0	3.7	2.3-4.8	33.5	16.2-53.5	57.6	37.7-74.0
Hybrid 891	48.2de	40.6-53.1	5.3	4.6-6.0	3.7	2.4-5.3	32.7	17.2-52.5	57.4	39.7-71.0
'Sputnik 71'	48.2e	39.5-54.2	5.2	4.4-6.4	3.9	2.3-5.4	35.1	17.0-54.8	54.8	36.6-73.0
Overall average	46.8		5.3		3.8		34.3		55.7	

[1]Dry-weight basis.

[2]Means followed by a common letter are not significantly different at the 5% level by Duncan's multiple-range test.

Table 4.—Oil content and fatty acid composition of the seeds of sunflower hybrids and varieties grown at 38 locations in 1977

[In order of increasing oil content]

Hybrid or variety	Oil content (%)[1]		Fatty acid composition (%)							
			Palmitic		Stearic		Oleic		Linoleic	
	Avg.[2]	Range	Avg.	Range	Avg.	Range	Avg.	Range	Avg.	Range
Sigco 894	44.7a	33.2-51.5	5.5	4.7-7.0	3.5	1.6-5.5	29.9	14.2-50.0	60.5	41.4-75.3
Big Top+	45.1ab	37.6-51.0	5.4	4.5-6.9	3.9	1.7-5.5	29.8	15.9-48.5	60.3	42.9-73.7
Cargill 204	45.2abc	35.3-51.5	5.6	4.5-7.0	3.5	1.9-5.7	29.5	14.6-50.4	60.9	40.2-75.9
Cal/West 903	45.3abc	37.0-51.6	5.2	4.1-6.6	4.2	2.4-6.1	30.6	14.5-51.2	59.6	39.8-74.1
Sunbred 223	45.3abc	37.6-50.6	5.5	4.7-6.7	4.0	1.9-5.6	31.9	15.5-55.2	58.2	35.2-74.3
Sun Hi 304	45.6bc	36.4-52.1	5.6	4.7-7.1	3.6	1.4-5.2	29.5	13.7-50.3	60.8	41.4-74.7
Sunbred 254	45.6bc	35.4-51.7	5.5	4.6-6.9	3.6	1.7-5.0	30.1	14.2-49.7	60.5	42.4-75.8
'Peredovik 66'	45.8bc	37.9-51.9	5.2	4.5-6.8	4.3	1.6-6.2	31.8	15.5-51.0	58.1	40.6-73.5
Cal/West 894	46.0c	35.7-51.5	5.8	4.5-6.8	3.7	1.9-6.1	29.7	14.8-52.7	60.6	38.1-74.3
Hybrid 8943	46.7d	39.2-51.1	5.2	4.3-6.6	4.5	2.2-6.3	32.5	14.5-59.2	57.6	32.4-74.0
Sun Gro 372A	47.5e	37.0-53.0	5.3	4.1-6.7	4.1	2.0-6.2	32.7	13.8-59.2	57.5	32.6-75.2
Sun Hi 301A	48.3ef	38.0-53.8	5.2	4.2-6.5	3.8	1.5-6.2	30.2	14.8-48.2	60.4	43.6-75.2
Sun Gro 380	48.3ef	36.9-53.0	5.2	4.3-6.4	3.9	1.8-5.7	30.2	13.8-50.0	60.2	41.4-75.8
'Sputnik 71'	48.8f	38.3-53.9	4.9	4.1-6.3	4.1	2.0-6.2	37.5	15.0-55.9	57.8	37.4-74.9
Overall average	46.3		5.4		3.9		31.1		59.5	

[1]Dry-weight basis.

[2]Means followed by a common letter are not significantly different at the 5% level by Duncan's multiple-range test.

Table 5.—Seed and oil yields of sunflower hybrids and varieties, 1976

[In order of increasing seed yield]

Hybrid or variety	Seed yield[1] (kg/ha)	Oil yield[2] (kg/ha)
Sunbred 223	1,961	899
'Peredovik 66'	1,967	901
Sun Gro 372	1,984	940
DO 410	2,024	953
Cargill 204	2,066	949
'Sputnik 71'	2,072	999
Sun Gro 380	2,109	1,013
Hybrid 8944	2,113	973
Sun Hi 301	2,118	1,001
Sun Hi 304	2,155	973
Sunbred 212	2,173	1,019
Hybrid 891	2,176	1,050

[1]Averages of 36 locations.
[2]Averages of 26 locations.

Table 6.—Seed and oil yields of sunflower hybrids and varieties, 1977

[In order of increasing seed yield]

Hybrid or variety	Seed yield[1] (kg/ha)	Oil yield[2] (kg/ha)
Sunbred 223	1,880	853
'Sputnik 71'	1,910	932
'Peredovik 66'	1,929	884
Sun Gro 372A	2,000	951
Sun Hi 304	2,023	921
Sun Gro 380	2,080	1,004
Hybrid 8943	2,093	978
Sigco 894	2,103	940
Sun Hi 301A	2,115	1,021
Cargill 204	2,120	958
Cal/West 903	2,136	967
Sunbred 254	2,137	974
Cal/West 894	2,184	1,004
Big Top +	2,241	1,010

[1]Averages of 40 locations.
[2]Averages of 38 locations.

in temperature. Oil contents of the seeds of sunflower, safflower, and castor bean were not affected by temperature. A comprehensive evaluation of the total oil contents at selected locations in our study supports Canvin's data on sunflower oil. For example, sunflowers grown at six locations in the Southeastern United States having an average temperature of 26.6° C during seed development had an average oil content of 48.7% compared to 48.5% for plantings at six locations in the Red River Valley of Minnesota and the Dakotas having an average temperature of 17° C.

For 1976 and 1977, temperature and latitude affected fatty acid composition highly significantly. Correlations between latitude as well as temperature (average, maximum, and minimum temperatures from flowering to harvesting) and fatty acid composition for the combined years 1976-77 were determined. The best correlations were obtained for minimum temperature. Oleic acid was positively correlated with minimum temperature ($r=0.87$), whereas palmitic ($r=-0.71$), stearic ($r=-0.57$), and linoleic ($r=-0.83$) acids were negatively correlated with minimum temperature. A linear regression model of linoleic acid content versus average minimum temperature during seed development showed a straight-line fit of the data, with $R^2=0.69$. Figure 1 is a plot of the actual data for both 1976 and 1977. Thus, if the average minimum temperature for the period from flowering to harvest at any given location is known, the linoleic acid content of sunflower seed with a standard deviation of $\pm 5.4\%$ can be predicted by the formula—percentage of linoleic acid=89.094-1.951 (average minimum temperature). Therefore, for each increase of 1° C in average minimum temperature, mean for linoleic acid would decrease by 1.95%.

Linoleic acid content correlated well with latitude ($r=0.78$) and average temperature ($r=-0.80$). The relationship between linoleic acid content and latitude is illustrated in table 7. In both 1976 and 1977, sunflowers planted by June 1 at 39° latitude or above generally had linoleic acid contents above 60%, with the exception of plants at locations near Davis, Calif., and Cortez, Colo. Plantings below 39° had linoleic acid contents below 60%. This observation could have important implications on the use of sunflower oil. Sunflower oil for products requiring high polyunsaturated oil, such as margarine and salad dressing, might be obtained from planting locations above 39° latitude; whereas, sunflower oil used in snack-food frying might be obtained from plantings located below 39°. However, as we indicated, there are exceptions to this observation. For example, late plantings of sunflowers in south Texas have had linoleic acid contents as high as 75%.

In this study, the exact time of seed phys-

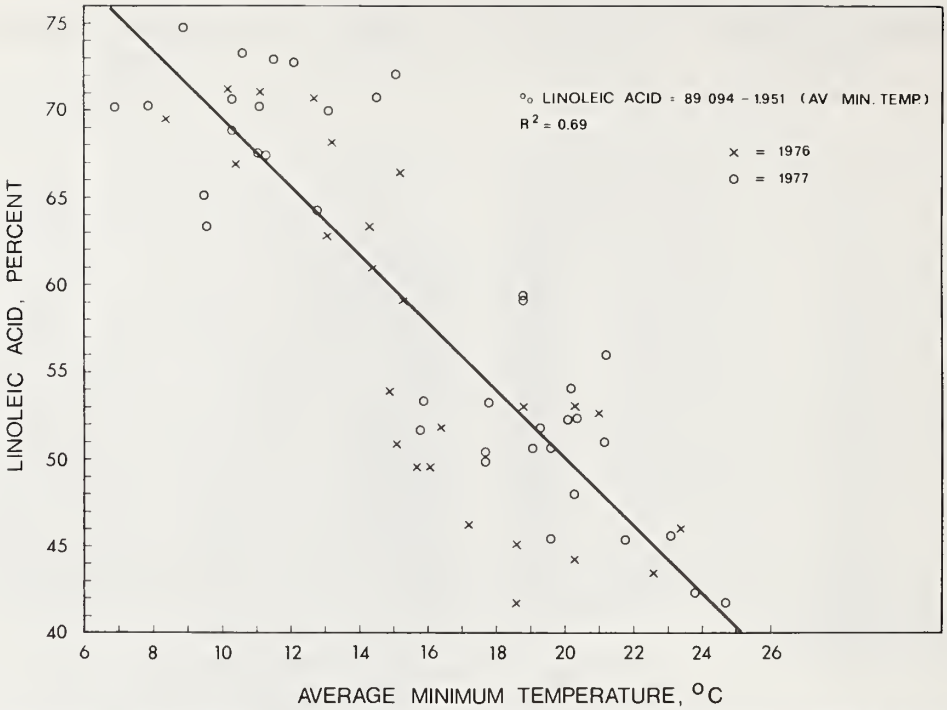

FIGURE 1.—Relationship between linoleic acid content and average minimum daily temperature during seed maturation, 1976 and 1977.

Table 7.—Effects of latitude and temperature on the oil content and fatty acid composition of sunflower seed samples from 22 locations in 1976 and 35 locations in 1977

Degrees latitude	Average temperature (°C)	No. locations	Average oil content (%)	Average fatty acid composition (%)	
				Oleic	Linoleic
		1976			
26 to 38.5	25.1	15	46.2	42.3	47.9
39 to 49	20.0	7	48.3	21.7	67.7
		1977			
26 to 38.5	26.6	20	45.9	40.3	50.7
39 to 49	18.2	15	46.6	19.8	69.4

iological maturity for some of the locations wasn't known, and the date of actual harvest was used to determine the average temperature data. Controlled studies, in which the seed are harvested at the same physiological maturity, would probably show that linoleic and oleic acids are better correlated with temperature and latitude than we have shown and would allow an even better prediction of fatty acid composition on the basis of planting location.

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